but is less than or equal to 75, Bidder #3's valuation for such a license.

Because the solution calls for Bidder #1 to obtain both licenses A and B, two more constraints are needed. First, the sum of Bidder #1's individual bids for licenses A and B must be equal to or exceed 175, the second highest valuation for the package (AB). Moreover, the sum of these two bids must be less than or equal to 200, Bidder #1's valuation for package (AB). Finally, the sum of the bids submitted by Bidders #1 and #3 must exceed 250, the second highest valuation for package (ABC), and be less than or equal to 275, the maximum valuation for licenses A, B, and C.

Taken together, these constraints imply that Bidder #1 must be willing to bid more than its stand-alone value for license B, and possibly A, if it wishes to obtain package (AB). For instance, we know with certainty that, in order to obtain package (AB), Bidder #1 must assign some synergy value to its bid for license B. However, it must do so carefully because it does not know whether it will acquire license A. If it does not, Bidder #1 will incur a loss in obtaining license B.

2. Interpretation

In the environment described above, a simultaneous-independent auction exposes a bidder to financial risk because each bidder must make a decision -- with limited information -- regarding the manner in which it should assign synergy values to a set of independent auctions.[23/] Because of this risk, such an auction may not assign the licenses efficiently. A sequential auction imposes an even greater burden on each bidder because, in contrast to a simultaneous-independent auction, it does not provide bidders in the early part of the auction much information regarding the likely sale prices of licenses that will be auctioned later.[24/] Absent this information, bidders in the early auctions are uncertain regarding how much of the synergy value derived from a package of licenses it should assign in such auctions. Compared to a simultaneous auction, a sequential auction appears to increase such uncertainty. This feature of a sequential auction will likely have adverse effects on economic efficiency and bidder fairness. The experimental results described in Section V substantiate this inference.

The solution to this problem is to employ a mechanism that does not force bidders to make decisions regarding the best way of assigning synergy values resulting from returns to scale in owning multiple licenses. Such a solution calls for permitting bidders to submit combinatorial or "package" bids for groups of licenses that yield returns to scale in value. Such a bid reduces financial

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23/ Recall that, although we know from the valuations that all three bidders want to package license A with license B, each bidder is uncertain about the other's packaging preferences.

24/ This point is echoed by Milgrom and Wilson, and McAfee. See Milgrom & Wilson, supra note 17 at 14; McAfee, supra note 9, at 7.

exposure and, thus, bidder uncertainty, thereby increasing the likelihood that the licenses will be assigned in an economically efficient manner.

If package bidding is permitted, the fundamental issue that remains is the types of packages of licenses that should be permitted. Specifically, should the Commission predetermine the allowable packages on which bids can be submitted, or should bidders be free to determine such packages? We believe that, in order to avoid misidentifying packages that create such returns to scale, bidders should be given the opportunity to select those packages that they believe will generate such returns. Moreover, as discussed in Section V, limitations on permissible packages will bias the PCS auction's outcome.

B. Heterogeneity in Bidder Preferences

The preceding example demonstrated that a non-combinatorial auction may have difficulty assigning licenses to those bidders that value them the highest when: (1) returns to scale exist, and (2) the package that gives rise to such returns to scale is the same across all bidders. The problem of assigning licenses to the highest-value bidders is exacerbated when the packages of licenses that give rise to such returns differ among bidders, and those different packages contain some common licenses. Indeed, the existence of non-perfectly overlapping bidder preferences regarding PCS licenses causes "heterogeneity" across bidders. Because of bidder heterogeneity, a non-combinatorial auction may either have significant difficulty in assigning PCS licenses in an economically efficient fashion or may simply be incapable of such an assignment.[25]

In its reply comments, NYNEX argued that full combinatorial bidding was "flawed" because "[w]hen each bidder is free to define the scope of its own combinatorial bid, the combinations may partially overlap, making it difficult to compare bids."[26] NYNEX, therefore, recommends that the Commission create sets of licenses for which combinatorial bids are permitted.

NYNEX correctly recognizes that bidder heterogeneity -- the existence of partially overlapping combinatorial bids -- may cause a "fitting" problem. However, NYNEX's solution to this problem -- the creation of non-overlapping sets of licenses -- is an unnecessary precaution. A combinatorial algorithm identifies the winning bidders by selecting that configuration of combinatorial and non-combinatorial bids that maximizes revenue. When the auction is operated in a continuous fashion, finding such a configuration is simple.

25/ The assignment problem caused by this environment is referred to as a "knapsack" or "fitting" problem by mechanism design experts.

26/ Reply Comments of NYNEX, Exhibit 1 at 18.

There is good evidence that the packages of PCS licenses that bidders desire will partially overlap. To examine the likelihood of such overlaps, consider two situations in which they will not occur. The first would be that all bidders attempt, are able, and seek, to acquire a nation-wide license. Comments submitted by different parties in this proceeding strongly suggest that this will not be the case.

One reason that this situation will not occur is the different budget constraints under which different bidders must bid. Because of differences in their financial resources underlying balance sheets, or because of imperfections in the capital markets, some bidders will experience a binding budget constraint at levels of license aggregation far below the national level. Indeed, even some of the most well-heeled bidders have expressed an interest in forming bidding alliances in an effort to assemble a larger PCS network.[27/] Many bidders do not have the interest or the financial capability of acquiring a national license. The evidence clearly indicates that not all bidders will be attempting to acquire a national license.

There is also no "fitting" problem when the preferences of bidders fall into discrete, mutually exclusive categories. This is the case, for instance, if there were different bidder "types" and all bidders within each type were interested in a collection of

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27/ Id., Exhibit 1 at 19-20.

licenses in which no other bidders were interested. There is ample evidence to indicate that bidder preferences overlap in a manner that will create a fitting problem. Overlapping preferences among bidders for certain PCS licenses will occur if two or more bidders view a given PCS license as an important component of their corporate strategy.[28/] The extent of the fitting problem, depends, in part, upon the number of bidders for whom that given PCS license is valuable. This, in turn, depends upon the variety of ways it can be used by bidders.

The Commission has defined PCS service broadly to permit a wide variety of uses for a PCS license.[29/] According to many in the industry, the spectra allocated to PCS service is capable of providing, when combined with the other needed inputs, a wide variety of telecommunications services.[30/] The variety of such services ranges from an enhanced cellular service to an input in the production process of an alternative access provider. The wide variety of services possible in the PCS allocation increases the

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28/ A fitting problem can involve bidders that are attempting to acquire disparate, non-adjacent PCS licenses because such licenses would complement the services that a bidder already provides in the geographic area covered by the PCS license.

29/ According to the Commission, PCS is "a family of mobile or portable radio communications services which could provide services to individuals and business, and be integrated with a variety of competing networks." Amendment of the Commission's Rules to Establish New Personal Communications Services, 7 FCC Rcd 5676, 5689, para. 29 (1992).

30/ See Telocator PCS Section, Marketing and Consumer Affairs Committee, Service Description Subcommittee, "PCS Service Descriptions" (Sept. 22, 1992).

number and type of firms that are interested in competing for PCS licenses and, therefore, increases the likelihood of a fitting problem.

It is not difficult to create examples of probable fitting problems. For example, cable television operators could desire PCS licenses that cover their franchise areas because PCS service may be an activity that is "complementary" to their existing activities,[31/] as could occur if they provide local telephone or access service. Moreover, cable operators may experience returns to scale in providing such services in their franchise areas.

However, other bidders may be interested in the same PCS licenses as cable operators, but for different purposes. Some of these bidders will desire such licenses because they also form a complementary relationship with their business activities. For instance, long-distance telephone service providers are likely to view PCS as a way of reducing the costs of completing calls over their networks. Local exchange carriers may desire some, but not all of the same licenses so that they can provide additional wireless service in their service areas -- which generally do not match precisely cable franchise areas.

31/ Activities are considered to be complementary if increasing one activity either increases or does not decrease the marginal profitability of the firm's other activities. See P. Milgrom & J. Roberts, Economics, Organization & Management 108-13 (1992).

Without a priori information on the distribution of valuations for PCS licenses, one cannot "prove" conclusively that a fitting problem will occur in the PCS bidding environment. We note, however, that there is partial overlap in the cellular networks in the New York and Los Angeles areas, among others.[32] For instance, Comcast's cellular network overlaps NYNEX's cellular network in two MSAs. Similarly, BellSouth's cellular network in southern California overlaps PacTel's cellular network in California in one MSA (Los Angeles).

Many of the conditions that give rise to this apparent heterogeneity are unexceptional. The service areas of numerous cellular networks overlap, presumably because of differences in, among other things, managerial capabilities and overall corporate strategies. We believe that similar overlaps in PCS service areas will exist for similar reasons and because of potential differences in PCS offerings. As a result, we expect that there will be many instances where bidder preferences for PCS packages will partially overlap.

1. Theoretical Analysis

Table 3 presents valuations in which returns to scale exist for certain license packages, and heterogeneity occurs -- that is,

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32/ Although there are important differences, the analogy between this example and the PCS bidding environment is not strained. The Commission's recent Pioneer Preference decision has reduced the number of MTA licenses to be auctioned from two to one in New York and Los Angeles.

bidders differ in regards to which package generates such returns.

TABLE 3: HYPOTHETICAL VALUATIONS - Returns to Scale and Bidder Heterogeneity

Bidder	(ABC)	(AB)	(BC)	(AC)	A	B	C
#1	250	200*	100	110	60	50	50
#2	255	110	200	100	50	60	50
#3	250	100	125	200	50	50	75*

* Denotes the economically efficient assignment.

The valuations contained in this chart satisfy the following conditions:

$V(ABC) > V(A) + V(B) + V(C)$ (applies to all bidders)

$V(AC) > V(A) + V(C)$ (applies to at least one bidder)

$V(AB) > V(A) + V(B)$ (applies to at least one bidder)

$V(BC) > V(B) + V(C)$ (applies to at least one bidder)

$V(ABC) > V(AB) + V(C)$ (applies to at least one bidder)

$V(ABC) > V(BC) + V(A)$ (applies to at least one bidder)

$V(ABC) > V(AC) + V(B)$ (applies to at least one bidder)

Based upon the valuations contained in this chart, economic efficiency is maximized when Bidder #1 obtains licenses A and B, and Bidder #3 obtains license C. As with the previous example, we can examine the difficulty a non-combinatorial auction may have in efficiently assigning such licenses by considering some of the price constraints that must be satisfied if the economically efficient assignment is to be an equilibrium assignment:

$$200 \geq P(A) + P(B) \quad \text{(for Bidder \#1)}$$

$$75 \geq P(C) \quad \text{(for Bidder \#3)}$$

$$200 \leq P(B) + P(C) \quad \text{(for Bidder \#2)}$$

$$75 - P(C) \geq 200 - P(A) - P(C) \quad \text{(for Bidder \#3)}$$

The first constraint states that, in order for Bidder #1 to obtain licenses A and B, the sum of their individual prices must be less than or equal to 200. Similarly, according to the second constraint, in order for Bidder #3 to receive license C, the price of license C must be less than 75, Bidder #3's valuation for such a license.

The third constraint states that in order for the optimal assignment to occur, the sum of the prices for licenses B and C must be greater than or equal to 200, the value that Bidder #2 assigns to such a package. Finally, the fourth constraint states that in order for Bidder #3 to obtain only license C, its "net profit" from obtaining only license C must be equal to or exceed its net profit from obtaining licenses A and C. Simplification through substitution yields the following impossible constraint.

$$200 \geq P(A) + P(B) \geq 250$$

This absurdity implies that, given the PCS license valuations listed in Table 3 and given a prohibition on package bidding, there does not exist a set of prices for licenses A, B, and C that satisfy the necessary conditions (i.e., constraints) for the efficient assignment -- to Bidders #1 and #3 -- of such licenses. More formally, the above condition implies that there does not exist a set of prices for licenses A, B, and C such that their assignment to Bidders #1 and #3 is an equilibrium assignment.

The absence of a set of prices that is consistent with the economically efficient assignment creates serious problems. For example, suppose the bid prices for licenses A, B, and C are 125, 75, and 75, respectively. At these prices, an assignment of licenses A and B to Bidder #1, and license C to Bidder #3 leaves each bidder satisfied. Suppose, however, that Bidder #2 decides to submit a bid of 76 for licenses B and C.[33/] Under these conditions, Bidder #1 loses license B because the price of B, combined with the price for license A, exceeds 200. However, by failing to obtain license B, Bidder #1 stands to lose 65 on its bid for license A [125 (bid) - 60 (stand-alone value for license A)]. In this instance, Bidder #1 may wish to withdraw its bid for license B. If Bidder #1 is not permitted to withdraw its bid, the simple auction creates a "last mover" advantage for the last

33/ Bidder #2 has an incentive to submit a bid of 76 for licenses B and C because, up until now, Bidder #2 has a zero payoff and such a bid provides an opportunity to earn 48 (=200 - 2(76)).

bidder.[34/] In this instance, Bidder #2 has such an advantage. A bidder can attempt to wait until other bidders have fully assigned their synergy values to different licenses and, when completed, increase its bid on those licenses it wishes to obtain. As in this example, not only may such a strategy be profitable (Bidder #2 earns 40 in this example), but it may also succeed in imposing a financial burden on a prospective competitor.[35/] Because of the potential for financial exposure, the competitor may be hesitant to bid aggressively, thereby reducing revenue and impairing economic efficiency.

If bidders are permitted to withdraw their bids, the absence of a set of prices that is consistent with the optimal assignment makes it difficult to determine the outcome of the bidding process. For example, permitting winning bidder to withdraw from the auction at zero cost, combined with the ability to re-enter, will cause the auction to continue indefinitely, with no clear end point. In this instance, it is not clear whether an equilibrium assignment of PCS licenses even exists. Moreover, if one or more equilibria do exist, the equilibrium that occurs will depend on the PCS licenses on which bidders first bid and the manner in which bidding

34/ We note also revenue is very high. In this instance, revenue is 277 (i.e., 125+76+76), which exceeds by 2 the maximum value for all licenses.

35/ Given any assignment and prices such that the net profits of those assigned are positive, some bidder will want to bid those prices higher as long as it considers only the gain, while ignoring the financial exposure from making such a move.

competition proceeds. However, as the implausible constraint indicates, if an equilibrium assignment is reached, it will not be economically efficient. In this situation, if a bidder is permitting to withdraw its winning bids at zero cost, revenue will be low because of low winning bids. If such bidders are not permitted to withdraw their bids, then revenue may exceed the maximum value for all licenses.

The solution to this problem is to permit bidders to submit bids for self-defined packages of PCS licenses. With package bidding, prices that satisfy the following constraints produce an equilibrium consistent with the efficient assignment of PCS licenses:

(1) $110 \leq P(AB) \leq 200$

(2) $P(AB) + P(C) \geq 255 \geq V(ABC)$

(3) $P(AB) + P(C) \geq 195 \geq V(A) + V(B) + V(C)$

(4) $P(AB) + P(C) \geq 260 \geq V(AC) + V(B)$

(5) $P(AB) + P(C) \geq 260 \geq V(BC) + V(A)$

(6) $50 \leq P(C) \leq 75$

where V(.) is the highest valuation for combination (.)[36/]

36/ These conditions are sufficient but not necessary. We choose them for their intuitive appeal. The necessary and sufficient conditions are:

(1) $200 > P(AB) > 185$

A price of 191 for the package (AB) and a price of 70 for C satisfy the above set of price constraints. The existence of such a set of prices eliminates the last mover advantage, thereby eliminating an important strategic component to the bidding process.

2. Interpretation

The preceding analysis indicates that non-combinatorial auctions are capable of assigning licenses in an economically efficient manner when there are no returns to scale in owning multiple licenses. In such a bidding environment, the Commission could select either a sequential or a simultaneous-independent auction to assign PCS licenses.

In a bidding environment where returns to scale exist and where the packages of licenses that give rise to such returns are the same among all bidders, the preceding analysis indicates that a non-combinatorial auction (e.g., simultaneous-independent or sequential auction) may have difficulty in assigning PCS licenses in an economically efficient fashion.[37] In such an environment,

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(2) $60 < P(C) < 75$

(3) $P(AB) + P(C) > 255$.

37/ An aftermarket may not eliminate the economic inefficiencies resulting from the use of a non-combinatorial auction in this environment. In order to solve the above fitting problem, bidders must be able to offer package bids for those packages that create the returns to scale in value. However, a non-combinatorial auction will likely assign the elements of such packages to different bidders. Because winning bidders in the bidders will be exposed to financial risk in attempting to assemble packages of PCS licenses. Because of the superior information it provides bidders on the expected winning bids for individual PCS licenses, a simultaneous-independent auction is likely to perform better than a sequential auction in assigning PCS licenses in this environment.

C. Merging Experimental Economics with Economic Theory

Beginning with Vickrey's seminal article, the theory of auctions has attracted considerable attention from economists in the last three decades.[38/] This work has led to a deeper understanding of price competition under conditions of asymmetric information between buyers and sellers. However, despite its rapid development, auction theory has not developed sufficiently to shed light on some important issues involving the economically efficient assignment of PCS licenses. Because of these concerns, NTIA asked Drs. John Ledyard and Dave Porter to examine, in an experimental setting, the performance properties of three different auction forms.

The usefulness of experimental analysis in the PCS auction policy debate is enhanced by the fact that the auction proposals

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auction may have difficulties in agreeing on how to divide the revenue from a package bid, such a bid may not resolve the economic inefficiencies.

38/ W. Vickrey, Counterspeculation, Auctions, and Competitive Sealed Tenders, 16 J. Finance 8 (1961).

submitted to the Commission fell into three decidedly different categories -- sequential, simultaneous-independent and, simultaneous combinatorial auctions. This created the opportunity for a careful experimental examination of the comparative performance characteristics of the three different auction forms.

The merger of economic theory and experimental analysis is creating a new area of economics called "mechanism design." In this field, the experimental lab serves the mechanism designer in the same way the wind-tunnel does the aeronautical engineer. Such testing makes it possible to design markets (e.g., auctions) capable of solving difficult economic problems. Based upon our knowledge of the telecommunications industry generally, and the wireless communications industry specifically, we believe that there is substantial merit to employing the field of mechanism design to analyze the problems of assigning PCS licenses in an economically efficient fashion.

V. Overview of Experimental Results

The Caltech researchers performed a series of economic experiments to examine the performance characteristics of three different auction forms -- sequential, simultaneous-independent, and simultaneous-combinatorial (the form on which NTIA based its EICA recommendations).[39] The outcomes of all three auction forms

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39/ Consistent with NTIA's EICA proposal, the simultaneous-combinatorial auction permitted bidders to use the stand-by queue to adopt a competitive strategy to defeat a package-were evaluated according to their ability to assign items (e.g., PCS licenses) in an economically efficient fashion and generate revenue.

The experiments were conducted in many different types of environments. For example, Dr. Charles Plott of Caltech conducted computerized experimental auctions for nine items (licenses) with eleven bidders.[40] In some trials, subjects received private valuations for each item individually, and a valuation for the package of nine items. In other trials, subjects received valuations for individual items and for two packages of three items.

Dr. Plott examined two basic auction mechanisms -- a sequential Japanese auction and a simultaneous-independent auction. Japanese auctions are akin to English oral auctions. In oral auctions the auctioneer continues to raise the price of the asset as long as one bidder indicates that he or she is willing to remain in the auction. In the simplest Japanese auctions, bidders begin by raising their hands. The auctioneer then increases the price of the auctioned item, and bidders exit the auction by putting down their hands when the auctioneer's price exceeds their willingness to pay for the item. The auctioneer raises the price until only

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bidder.

40/ Dr. Plott's experiments were sponsored by Pacific Bell and Nevada Bell. We thank Dr. Plott and his sponsors for making his results available.

one bidder remains. The key difference between the English and Japanese auctions is that, in the Japanese auction, bidders are certain about which participants remain. In Dr. Plott's computerized version of the Japanese auctions, however, bidders knew how many other bidders remained in an auction, but did not know their identities.

Each bidder in Dr. Plott's sequential experiments first submitted a sealed package bid for the nine items.[41/] The highest package bid was publicly announced via computer before the sequential auctions for individual items. After the announcement, the individual items were auctioned sequentially -- that is, one after another. The sum of the high bids in the individual auctions was compared with the highest package bid to determine whether the items would be assigned on an individual or on a collective basis.

In Dr. Plott's simultaneous-independent environment, subjects submitted bids on the nine items simultaneously. Bids were for individual licenses, not for packages of licenses. A bidder attempting to amass all nine licenses might be forced to bid above its valuations on individual licenses, only to lose money in the event that completing the package proved too difficult. To minimize this "exposure" problem, some of Plott's simultaneous-independent auctions employed a "release provision" which allowed

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41/ In some experimental trials, the sealed bid was for a pre-specified collection of seven of the nine licenses.

bidders to withdraw bids, but at a penalty equal to the difference between the withdrawn bid and the final sales price of the item. If the item eventually sold at a price above the withdrawn bid, the bidder paid no penalty. In other experiments, no bid withdrawal was permitted.

Dr. David Porter of Caltech conducted experimental auctions in three different environments -- one with three bidders and three auctioned items, one with five bidders and six items, and another with ten bidders and 54 items. In the three-item experiments bidders received private valuations for individual items and a valuation for the three-item package. Bidders who amassed only a two-item package received a payoff based on the highest individual item valuation in their package. In the six-item experiments, bidders received valuations for a variety of packages. These packages overlapped across bidders so as to create fitting problems.

In the 54-item environment, bidders received valuations (which contained both private and common value elements) for each individual item and for packages. The 54 items (licenses) were arranged in a rectangular grid (six rows, nine columns). For most of the bidders, these synergistic packages centered on a nine-item "region." One bidder, however, received synergies from acquiring all 54 items. In some trials, the "large" bidder's valuations for all licenses surpassed the sum of the highest regional bidders' valuations. In others, the reverse was true. Because most bidders' valuations in the environment were based on non-overlapping regions, Dr. Ledyard and Dr. Porter indicated that "fitting problems" were not very severe in this environment.

Dr. Porter tested three mechanisms in the three-item and six-item environments -- a simultaneous-combinatorial auction, a simultaneous-independent auction, and a sequential Japanese auction.[42/] In the 54-item environment, he tested only the two simultaneous mechanisms. The simultaneous-combinatorial mechanism required an adaptation of the AUSM (the Adaptive User Selection Mechanism) software originally developed at Caltech on behalf of NASA and the Jet Propulsion Laboratory. AUSM permits bidders to bid for any package of the available items in the experiment.

In experimental environments where fitting problems occur, bidders need information about how to craft their bids to resolve potential overlaps with other bidders. AUSM permits bidders the opportunity to coordinate their bids through a feature, discussed briefly above, called the stand-by queue.[43/] The queue is a computer bulletin board that contains standing offers from all

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42/ Instructions that were given to bidders at the beginning of these experiments appear in the appendices. The 3-bidder, 3-item instructions appear in Appendix B. The 5-bidder, 6-item instructions appear in Appendix C. Descriptive notes on how valuations were drawn in the 10-bidder, 54-item environments appear in Appendix D. We thank Dr. David Porter of Caltech for furnishing this information.

43/ See supra note 4.

bidders on packages of licenses. A bid that is part of the queue is, by definition, not part of the provisionally accepted (i.e., the current revenue maximizing) allocation. A bidder can, however, combine these standing offers with its own bid to displace bids in the provisionally accepted allocation.

In Dr. Porter's simultaneous-independent environment, as in Dr. Plott's, subjects submitted bids on all items simultaneously, but no package bidding was permitted. In Dr. Porter's three-item and six-item experiments, the bid withdrawal rule permitted a bidder to withdraw a winning bid on any item. However, if a bidder withdrew a bid on one item, all of its bids were declared null and void for that trial. This was a much more "strict" withdrawal rule than the release provision employed by Dr. Plott.

Unlike Dr. Plott's sequential Japanese auctions, Dr. Porter's were conducted orally. As a result, bidders knew the identities of those who remained in the auction. Also, whereas Dr. Plott employed a sealed bid for all items previous to the Japanese auctions for individual items, Dr. Porter used a Japanese auction for the entire collection of items, followed by Japanese auctions for individual items. If the sum of the high bids in the individual auctions was above the high bid for the collection, the items were awarded on an individual basis. If not, the items were assigned as a package.

Regardless of the environment chosen by Dr. Porter, the simultaneous-combinatorial auction outperformed the sequential and simultaneous-independent auctions in terms of economic efficiency. The simultaneous-combinatorial auction is, therefore, the most "robust" auction form for the environments chosen. This robustness is due to the simultaneous-combinatorial auction's superior ability to shield bidders from the hazards of financial risk. We believe that the robustness of the simultaneous-combinatorial auction to different bidding environments is an important characteristic.

The economic experiments also revealed that commenters' concerns regarding the tendency for full combinatorial bidding to cause a free-rider problem are overblown. The efficiency levels achieved indicate that bidders effectively used the stand-by queue in the Caltech researchers' implementation of an EICA to counteract package bids. Finally, the economic experiments indicate that both the simultaneous-independent and sequential auctions create unique strategic problems for bidders. For instance, Dr. Plott's simultaneous-independent auction experiments indicate that some bidders, in an attempt to make another bidder's acquisition of a set of licenses more costly, bid <u>above</u> their valuations for individual licenses. Therefore, when a combination bidder did assemble its desired package of licenses, it did so at significant expense.[44/] Similarly, Dr. Plott's sequential Japanese auction

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<u>44</u>/ Many bidders may wish to assemble a package containing numerous PCS licenses. According to the experimental analyses, these bidders may not be able to acquire such

results indicate that when a package bid for all items is publicly known, some bidders may have an economic incentive to bid above their valuations on individual items, increasing the likelihood of an inefficient assignment of PCS licenses.

A. Sequential Auctions and Economic Efficiency

We remain convinced that sequential auctions do not adequately capture the geographic and spectrum-related interdependencies in the value bidders place on PCS licenses.[45/] In a sequential auction, when a bidder's value for some collection of PCS licenses is greater than the sum of its values for the individual licenses in the collection, the bidder may have to decide when to reveal, in the form of a higher bid, these potential "synergies." However, bidder uncertainty regarding the bidding competition on licenses to be auctioned later in the sequence makes it difficult to know when to reveal these synergies. If the bidder bids too aggressively early in the sequence, it may not be possible to acquire necessary licenses auctioned later. If the bidder does not bid aggressively enough early in the sequence, it may forego the opportunity to obtain its desired combination. Sequential auctions, therefore, often produce relatively inefficient allocations.

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licenses when economic efficiency would dictate that they should. Moreover, when they do acquire such licenses, these same bidders may pay substantially for these licenses.

45/ NTIA Staff Paper, supra note 14, at 58-65.

The experiments confirm these qualitative concerns about sequential mechanisms. In the nine-item, eleven-bidder experiments conducted by Dr. Plott, a simultaneous-independent mechanism with the "release provision" consistently produced a more efficient allocation than did the sequential Japanese auction with a sealed package bid (See Table 4).[46] Although the efficiencies are relatively similar in the nine-item package experiments, there is a more pronounced disparity between the two mechanisms in the experiments in which bidders had valuations for three-item packages.

TABLE 4: PERFORMANCE OF VARIOUS AUCTION MECHANISMS IN DIFFERENT ENVIRONMENTS

Environment	Mechanism	Average Efficiency (as a % of optimum)	Average Revenue (as a % of optimum)
11 X 9 (Plott) [3-item packages]	Simul.-Indep.	98.5%	*
	Seq. Japanese	89.6%	*
11 X 9 (Plott) [9-item packages]	Simul.-Indep.	95%	*
	Seq. Japanese	92.5%	*
3 X 3 (Porter)	AUSM	92%	73%
	Seq. Japanese	84%	77%
5 X 6 (Porter)	AUSM	92%	70%
	Seq. Japanese	57%	61%

*-Dr. Plott did not calculate revenues as a percent of optimum.

46/ The nine-item experiments done on behalf of Pacific Bell and Nevada Bell did not test the performance of a simultaneous-combinatorial mechanism.

Bidding behavior in the nine-item experiments points out another undesirable feature of sequential Japanese auctions that permit a sealed package bid. When a sealed bid for all nine items exists and is known to the bidders, those bidders who obtain items early in the sequence of Japanese auctions have profits[47/] that can only be realized if the sealed bid is defeated. They often, therefore, have an incentive to bid above their valuations for items auctioned later in the sequence to ensure the defeat of the sealed bid. As Dr. Plott notes, "The existence of the sealed bid harms the profits on the items that come late in the sequence."[48/] Bidding above one's valuation, moreover, can lead to inefficient allocations.

As described above, Dr. David Porter of Caltech conducted a slightly different form of the sequential Japanese auction experiments in his three-bidder, three-item and the five-bidder, six-item environments.[49/] In both of the environments, the

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47/ "Profits" refer to the difference between the bidder's valuation for an item and the price at which it won the auction.

48/ Dr. Charles Plott, "Uses of Laboratory Experimental Methods in the Design of the PCS Design" at 2 (personal notes used at the NTIA/Caltech PCS Auction Demonstration, provided in Appendix A.) We thank Dr. Plott for making the details of his experimental design available to us.

49/ Porter's sequential experiments were run at the end of his simultaneous-independent and AUSM trials. The subjects were, therefore, familiar with the experimental environment -- that is, the way valuations were created -- by the time the sequential auctions occurred. Such familiarity with the experimental environment is said to "contaminate" a subject pool, making it difficult for the experimenter to infer how